

Geographical distribution of wild *Daucus* species in the natural grasslands of the Argentinian pampas

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Abstract Three wild carrot species have been reported in the argentinian flora: *Daucus montanus* Humb. et Bonpl. ex Schult., *D. montevidensis* Link ex Sprengel and *D. pusillus* Michx. There is a discrepancy among authors about the distinctive morphological traits of the last two species; thus, it is difficult to ascertain if they are truly two distinct taxa. Based on the available literature and in the search of a paradigmatic site, four collection trips were carried out in 2004 and 2005 in Buenos Aires and Southern Entre Ríos provinces. Populations were sampled at 30 sites, and local environmental parameters and associated plant species were recorded. Morphological observations and chromosome counts were carried out on 10 plants/population. Three morphological phenotypes were distinguished: one in 18 populations, all with $2n = 2x = 18$, and two in the

remaining 12, with $2n = 2x = 22$ or aneusomaty ($2n = 2x = 20, 22$). Populations of the first phenotype were assigned to wild *D. carota* and the rest, tentatively, to *D. pusillus* (*D. montevidensis*?), till further evaluations are carried out in test sites to verify this tentative conclusion.

Keywords Carrot · *Daucus carota* L. · *D. montevidensis* Link ex Sprengel · *D. pusillus* Michx · Wild species

Introduction

The conservation of plant genetic resources is of fundamental importance for maintenance and enhancement of agricultural production. Genetic variability is essential for developing new cultivars to cope with adverse biotic and abiotic factors that are constantly eroding the system, as well as to introduce desirable culinary, nutritional and processing traits, among others. Without genetic variability, the progress from selection is nil.

Natural sources of genetic variability include commercial cultivars, heirloom varieties, landraces and wild species. Genetic variation can also be induced by mutagenesis or introduced through transgenesis, but the former is unreliable and usually generates deleterious variation, while the latter ultimately relies upon natural diversity as well. As Swanson (1996) has stated, the vast

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majority of crop research and development in the world is undertaken with cultivars, but there is a constant need for a regular introduction of “new” genetic materials from natural sources into breeding programs because the stock of information within the agricultural research and development system tends to depreciate annually and must be renewed from external sources at the same rate.

Carrot (*Daucus carota* L. var. *sativus* Hoffm., $2n = 2x = 18$) is the major vegetable umbellifer cultivated worldwide. While cultivated carrot has its center of origin in Central Asia, the genus *Daucus* is most diverse in the Mediterranean region, particularly in North Africa, where strong speciation has taken place. The results of a worldwide morpho-anatomical study (Sáenz Laín 1981) led to the recognition of 20 *Daucus* species: the common carrot, one Australian species, three other species native to the Americas and 15 Mediterranean species, grouped into five sections. More recent estimates place the number of species in the genus at around 25 (Rubatzky et al. 1999).

The number of accessions of *Daucus carota* and other closely related species held in germplasm collections around the world is relatively small, approximately 5,600, of which 1,000 are held at the Vavilov Institute in Russia. Other important collections are held at the Genetic Resources Unit of Horticultural Research International, Wellesborne, Warwick, UK, and at the US Department of Agriculture North Central Region Plant Introduction Station in Ames, Iowa; most of the accessions belong to *D. carota* and only around 5% of them to other species (Rubatzky et al. 1999).

According to Sáenz Laín (1981), the three species found in the Americas are *D. montanus* Humb. et Bonpl. ex Schult. (= *D. australis* Poepp. ex DC. = *D. toriloides* DC.) of section *Anisactis*, distributed in Mexico, Perú, Venezuela, Colombia and Chile, and two species belonging to section *Daucus* along with the common carrot: *D. montevidensis* Link ex Sprengel (= *D. hispidifolius* Clos), distributed in Argentina, Uruguay and Chile, and *D. pusillus* Michx., distributed in USA, Mexico and Chile. Similarly, Heywood and Dakshini (1971) indicated that *D. pusillus* is

native to North America and *D. montevidensis* to South America.

For the Argentinian flora, *D. montevidensis* has been cited as a common species in sandy soils of Buenos Aires province (Cabrera 1953), growing in the “flechillar,” a plant community of indigenous grasses (*Stipa*, *Aristida*, *Piptochaetium*) in high and fertile fields of the Salado basin (Vervoorst 1967), and in the provinces of Córdoba, Entre Ríos, and Corrientes (Marzocca 1957). Notwithstanding, and for the same type of soil, Cabrera (1965) and Cabrera and Zardini (1978) described *D. pusillus* as a synonym of *D. montevidensis*, but did not make any reference to chromosome numbers. On the other hand, *D. pusillus* has been cited as a temperate climate species of both South and North America, with $x = 11, 10$ (?), usually growing in Argentina in dry and sandy soils in Patagonia (Correa Maevia 1988). According to Lincoln Constance (Correa Maevia 1988), this species is a synonym of both *D. montevidensis* and *D. hispidifolius*. The morphological and anatomical details presented to describe the species (Cabrera 1953, 1965; Marzocca 1957; Cabrera and Zardini 1978; Correa Maevia 1988) are confusing as are the annotations found on Argentinian herbarium vouchers; in addition, there are no precise records of the collection sites except for the soil type.

Given the economic importance of carrots for both human and animal consumption and for the cosmetic and pharmaceutical industries, the low number of wild *Daucus* accessions available in world germplasm banks (Rubatzky et al. 1999) and the susceptibility of the cultivated species to pests and diseases, the value of collecting germplasm of closely related species is potentially high. Towards that end, the objectives of this paper are to report the results of four trips carried out in the pampas grasslands of two Argentinian provinces, Buenos Aires and Entre Ríos, to collect and document wild *Daucus* germplasm.

Materials and methods

Collections trips were planned on the basis of information obtained from Cabrera (1953, 1965), Marzocca (1957) and Vervoorst (1967),

herbarium specimens — collected over a period of over 100 years — that are available at the Facultad de Agronomía, Universidad de Buenos Aires (FAUBA) and the Centro Nacional de Investigaciones Agropecuarias, Instituto Nacional de Tecnología Agropecuaria (CNIA, INTA), Argentina, and in the search of paradigmatic sites in the provinces of Buenos Aires and Entre Ríos.

Populations growing at least 20 km apart were sampled. Ripe fruits were collected from 10 or more plants per site. Observations were made on plant height, number of branches/plant, stem and leaf pubescence and color, leaf blade length, width and dissection, umbel arrangement and diameter; number and length of umbel rays, flower color, presence/absence of a central colored umbelet, and fruit size, shape and number of ridges, spines and ducts. Local environmental parameters, such as altitude, soil type, average annual temperatures and rainfall, and associated plant species were recorded.

Chromosome counts were carried out on 10 plants per accession following the standard technique of pre-treatment with 8-hydroxyquinolin (0.29 g/l) for 2 h, fixation in 3 ethanol: 1 glacial acetic acid (v/v), hydrolysis in 1 N HCl at 60°C for 12 min and staining with leucobasic fuchsin (Coleman 1938).

Seed samples were air-dried for 6 months and, then, stored in aluminum foil envelopes at 4°C at the Laboratory of Genetics, EEA Balcarce, INTA-FCA, UNMdP, Argentina, for conservation and further genetic studies, where they are available for distribution upon request.

Results

Four collection trips (totalling approximately 4000 km) were carried out in Argentina: in the first and in the last week of January 2004, covering the Salado River Basin (Buenos Aires Province = Bs. As.); in the last week of December 2004, covering the Sierra de la Ventana area (Bs. As.); and in third week of January 2005, covering the Samborombón Bay (Bs. As.), Martín García Island (in the confluence of the rivers Uruguay and Río de la Plata), and in Southern Entre Ríos Province (Fig. 1).

Thirty sites were sampled (Table 1). During the first trip, *Daucus* plants were in bloom but did not bear ripe fruits so populations were not sampled. During the second trip, most plants were in bloom and also bore ripe fruits, so populations were sampled. During the third and fourth trips, plants were completely dried (some of them had already shed their fruits) and fruits could be easily collected. Populations observed during the first two trips were very large (100–1,000 or more plants). During the last two trips, some of the observed populations were smaller but still relatively large (100 or more plants). Populations could be grouped into three clearly distinct morphological phenotypes that were designated 1, 2 and 3.

Phenotype 1 (Fig. 2) closely resembled the phenotype of wild *D. carota*, as described by Sáinz Laín (1981) and Correa Maevia (1988): plants were up to 150 cm tall, hispid, with 2–3 pinnate, usually highly dissected, glabrous to pubescent leaves, with or without anthocyanins. Umbels were variable in shape, most frequently convex with curved rays (nest-like) and rarely flat-topped with straight rays; petals were white to reddish, and those of the central umbelet were sometimes very dark purple; fruits had two rows of simple scattered straight hairs and their cross-sections were trapezoidal to rounded, with six oil ducts; secondary ridges on the fruits had a row of 12–20 spines (Fig. 3). The latter two phenotypes (Figs. 4, 5) resembled the ones depicted in the literature (Cabrera 1953; Marzocca 1957) that had been indistinctly classified as *D. pusillus* and/or *D. montevidensis* in the herbaria consulted; these two phenotypes differed from each other only in plant height and number of branches (5–10 cm tall with 1–4 branches vs. 50–70 cm tall with 5 up to many branches). Both phenotypes were very pubescent, had highly dissected leaves, flat-topped umbels with straight rays and fruits with two rows of simple scattered straight hairs and secondary ridges with a row of 12–15 spines of various lengths with respect to fruit width: from very short (1/4 or 1/3) to very long (two times). Fruits in cross-sections were also of various shapes, from almost triangular to trapezoidal or almost rounded, with six oil ducts (Fig. 6). Leaf shape and dissection in phenotype 1 was clearly

Fig. 1 Collection routes in Buenos Aires and Entre Ríos provinces, Argentina; 2004 and 2005



distinct from the other two phenotypes (Fig. 7). Fruit size, in contrast, was variable in all three morphological phenotypes.

All accessions from the Salado River Basin, also known as the Flooding Pampa, had phenotype 1 and were $2n = 2x = 18$ (Fig. 8), except for the accession from 25 de Mayo. Populations of this phenotype, which bore ripe fruits in late summer, occurred in upland flechillar grassland communities, usually modified by agriculture, but were even more abundant along roadsides, dirt roads and other modified environments. Associated species were very variable, although always typical of those environments, and included: grasses such as *Dactylis glomerata* L., *Paspalum dilatatum* Poir., *P. quadrifarium* Lam., *Cynodon dactylon* (L.) Pers., *Stenotaphrum secundatum* (Walter) O. Kuntze, legumes such as *Medicago sativa* L., *Trifolium repens* L., *Lotus glaber* Miller, *Melilotus alba* Medik., composites such as *Aster squamatus* (Spreng.) Hieron., *Hypochaeris radicata* L., *Carduus acanthoides* L., *Xanthium*

spinosum L., *Centaurea calcitrapa* L., umbellifers such as *Ammi majus* L., among others. In this area, with saline and sodic soils and only 100–200 m.a.s.l., the climate is subhumid temperate, with average maximum and minimum annual temperatures, respectively, of 21°C and 10.5°C in the northern part and of 20°C and 7.5°C in the southern part; rains are well distributed year around, with an average of 1,000 mm/year (Moscatelli and Scoppa 1983).

In contrast, all accessions from Sierra de la Ventana, Bahía de Samborombón and Médanos, that bore ripe fruits at the beginning of summer, had phenotypes 2 and/or 3 and were typically $2n = 2x = 22$ (Fig. 9), although cells with $2n = 2x = 20$ were also observed at a low frequencies (less than 10%). The Ventania System, to which Sierra de la Ventana belongs, is formed by mountain ridges reaching 1250 m.a.s.l. Vegetation is dominated by *Paspalum quadrifarium* and *Eryngium eburneum* Decne. Mesic sites are covered with *Cortaderia selloana* (Schult.) Asch.

Table 1 Accessions and their collection sites in Buenos Aires and Entre Ríos provinces (2004 and 2005)

Site	Province and area Buenos Aires	Location	Accession
1	Salado Basin	Route 29, 58 km from Balcarce	ECMC car 1
2		Route 29, 85 km from Balcarce	ECMC car 2
3		Route 50, from Ayacucho to Rauch, 10 km from cross-roads	ECMC car 3
4		Route 50, 22 km from site 3	ECMC car 4
5		Route 50, 24 km from site 4	ECMC car 5
6		Route 30 from Rauch to Las Flores, 42 km from site 5	ECMC car 6
7		Route 30, from Rauch to Las Flores, 600 m from the entrance to Miranda	ECMC car 7
8		Colman, 8 km from site 7	ECMC car 8
9		Route 3, from Las Flores to Azul, bordering Channel 11	ECMC car 9
10		Road to Pardo, 1 km from the bridge on Channel 11	ECMC car 10
11		Route 3, from Azul to Las Flores, 3 km from Azul	ECMC car 11
12		Route 60 from Azul to Rauch, 3.5 km from Route 3	ECMC car 12
13		Route 226, km 206–207	ECMC car 13
14		Route 226, km 171	ECMC car 14
15		Route 226, km 202	ECMC car 15
16		General Lavalle site 1	ECMC car 16
17		General Lavalle site 2	ECMC car 17
18		General Lavalle site 3	ECMC car 18
19		25 de Mayo	ECMC pus 5
20	Sierra de la Ventana	In front of Hotel Provincial	ECMC pus 1
21		Abra El Pantanoso	ECMC pus 2
22		Cerro Bahía Blanca	ECMC pus 3
23		Dique-Cerro del Amor	ECMC pus 4
24	Samborombón Bay	Punta Rasa	ECMC pus 6
25		Route 11, km 22	ECMC pus 7
26		Route 11, km 162	ECMC pus 8
27		Route 56, km 21	ECMC pus 9
28		Route 11, Stream El Porteño	ECMC pus 10
29	Other	Martín García Island	ECMC pus 11
30	Entre Ríos South	Médanos	ECMC pus 12

Fig. 2 Natural population of phenotype 1

Fig. 3 Examples of fruits of phenotype 1 from sites 1 (**a**) and 2 (**b**) in General Lavalle, Buenos Aires

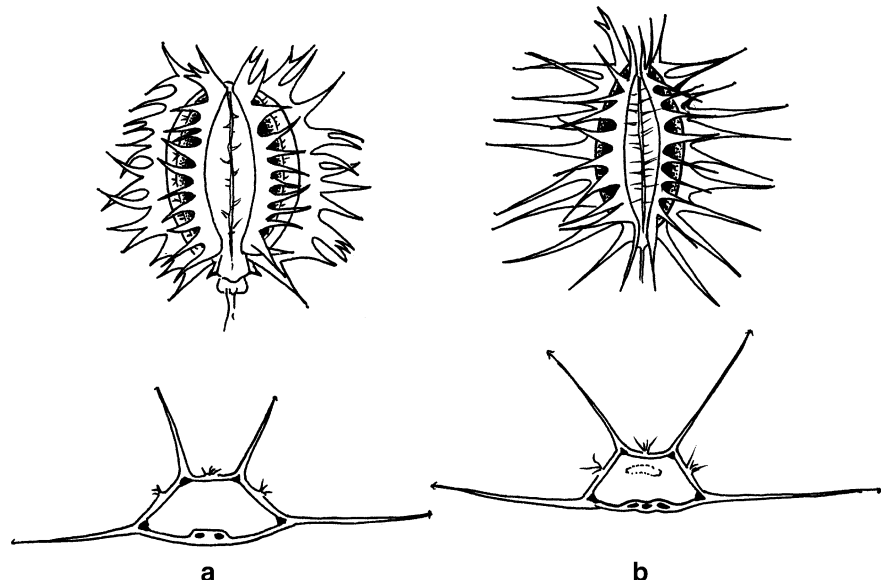


Fig. 4 Natural population of phenotype 2 from Cerro del Amor, Buenos Aires



In deep well-aerated soils, there is abundance of *Colletia paradoxa* (Spreng.) Escal., *Dodonaea viscosa* (L.) Jacq. and species of *Buddleia*, *Baccharis*, *Cestrum*, *Vernonia* and *Discaria* (Parodi 1940; Frangi and Bottino 1995). The climate is cooler and drier than in the southern limit of the Flooding Pampa, with annual rains ranging between 700 mm and 900 mm and common snowfalls in the mountains. *Daucus* was found in

varied soils, from litic on low altitude slopes to rather deep at the base of hills. The Bahía de Samborombón, in contrast, forms a coastline corridor approximately 180 km long and two to 23 km wide that constitutes the eastern limit of the Flooding Pampa (Soriano 1991). It includes a portion of shallow intertidal lands in the Río de la Plata estuary at an elevation of about 3.5 m.a.s.l. This environment presents a dense array of



Fig. 5 Natural population of phenotype 3 from Cerro Bahía Blanca, Buenos Aires

swamps and salt marshes dominated by *Spartina montevidensis* Arech. Low soils, which are common in this region, have very limited water conductivity and high salinity. The climate is subhumid temperate. The vegetation is composed of short and tall grasses, except along the coast, where a ridge of shell soils is covered by a rather sparse and varied forest that is a continuum of the *Celtis tala* Gill. ex Planh. forest of Northeastern Argentina. Lowland and humid communities with dominant C4 grasses and graminoids are frequent; along with *Leersia hexandra* Swartz, *Paspalum vaginatum* Swartz., *Paspalidium paludivagum* (Hitch. et Chase), *Cyperus* sp., *Juncus imbricatus* Laharpe var. *chamissonis* (Kunth) Buch.; the saline soil communities are dominated by *Distichlis scoparia* (Kunth) Arechav. and *D. spicata* (L.) Greene and the salt marshes by *Spartina montevidensis*. At the most humid places, where surface water accumulates during winter, it is common to find *Solanum glaucum*

Dum. ex DC. and species of *Juncus* and *Typha*, among others.

Martín García Island is situated in the confluence of the Uruguay River and the Río de la Plata, at 27 m.a.s.l. The average annual temperature and humidity are, respectively, 17°C and 81%, with an annual rainfall of 1,000 mm. Its climate and ecological characteristics are similar to those of the Delta islands close to Buenos Aires. Its vegetation is typical of sandy soils, forest in gallery and subtropical forest of Northeastern Argentina (Soriano 1991). In Southern Entre Ríos Province, the climate is also temperate and soils are rich, similar to those of the Northern Pampas of Buenos Aires Province; however, strips of sandy soils and dunes are frequent at the locality of Médanos. Grasslands of this area are characterized by species of *Axonopus*, *Paspalum*, *Digitaria*, *Schizachyrium* and *Bothriochloa*, and the paucity of *Piptochaetium*, *Poa* and *Stipa* in comparison to the Southern grasslands. However, there are also local communities dominated by *Stipa neesiana* Trin. et Rupr., *S. tenuissima* and *Eragrostis ciliarensis* (All.) Link. Although the macroenvironments of these areas differed, *Daucus* populations were consistently found in sandy soils; moreover, the only population of phenotype 3 found in the Salado River Basin grew in a sandy strip within an alfalfa and red clover pasture.

Discussion

Native grasslands in the Argentinian pampas have been extensively disrupted by agriculture. However, mountain ranges, riparian areas and sand dunes maintain an almost natural vegetation with low to fair levels of disruption by grazing cattle.

The four exploration trips were designed on the basis of old information and with rather inconsistent botanical descriptions. However, with relative ease, we found populations that were distinguishable by their morphological characters, had different chromosome numbers and were adapted to paradigmatic habitats. Thus, they could be unmistakably assigned to different taxa. Populations with phenotype 1 undoubtedly represent wild *D. carota* whereas populations with

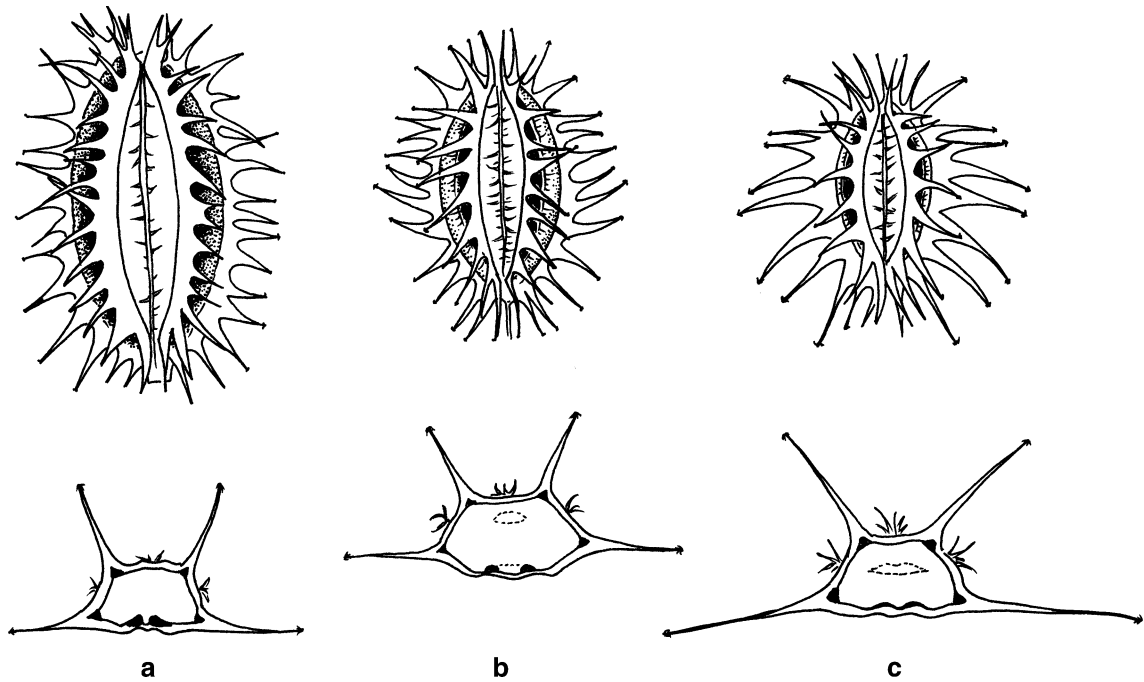
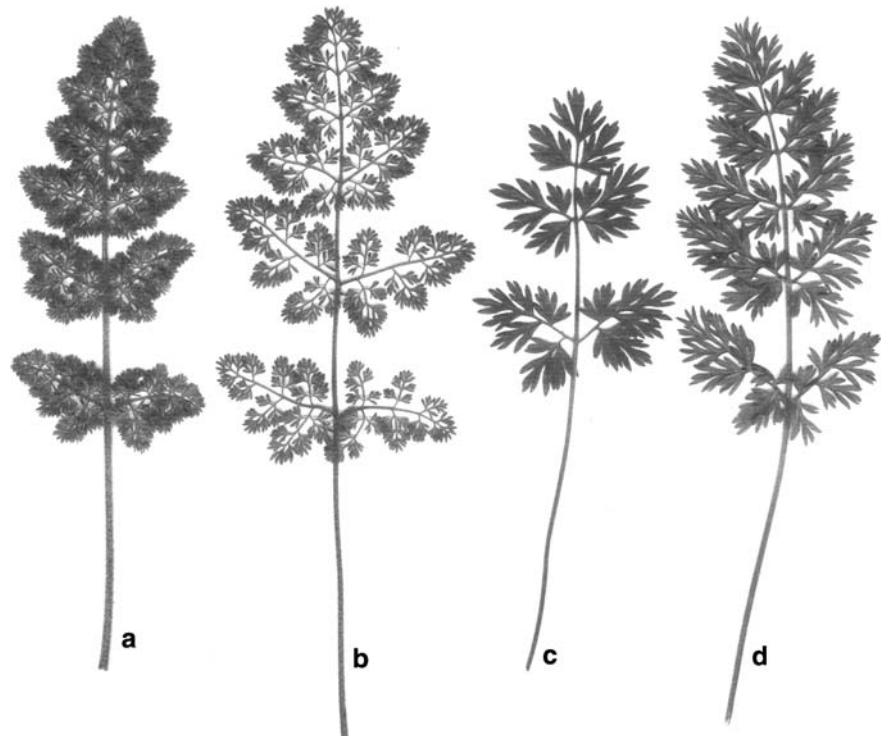


Fig. 6 Examples of fruits from (a) Cerro Bahía Blanca, phenotype 3, (b) Abra El Pantanoso, phenotype 2, (c) Bahía de Samborombón, phenotype 3; Buenos Aires

Fig. 7 Leaves of phenotypes 2/3 (a, b) and phenotype 1 (c, d)



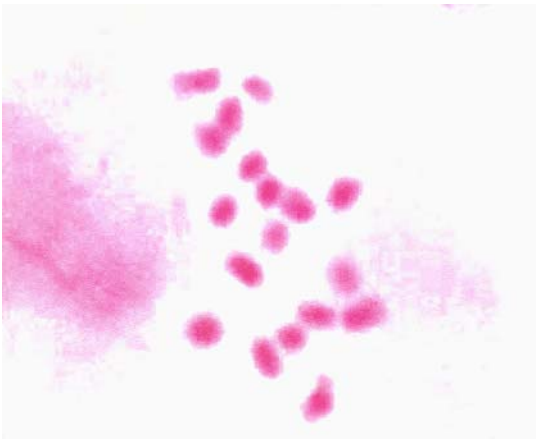


Fig. 8 Phenotype 1: metaphasic plate with $2n = 2x = 18$ (assigned to *D. carota* L.); 1000×

phenotypes 2 and/or 3 could represent either one other or two other different species (either *D. pusillus* or, if two different taxa can be recognized, *D. pusillus* and *D. montevidensis*). The published botanical descriptions of these two species partially overlap and it is difficult to ascertain, from the drawings in the publications, if they represent different taxa or are actually synonymous. Based on the large morphological variability that we observed in natural populations, herbarium specimens and published drawings, and until molecular studies are carried out, we will follow the nomenclature of Cabrera (1965), Cabrera and Zardini (1978) and Lincoln Constance (in



Fig. 9 Phenotype 2: metaphasic plate with $2n = 2x = 22$ (assigned to *D. pusillus* Michx.); 1000×

Correa Maevia 1988), and tentatively consider all the accessions with $2n = 2x = 22$ as *D. pusillus*. Further evaluations of progeny from diverse populations grown together in test sites will be useful in testing this tentative conclusion.

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